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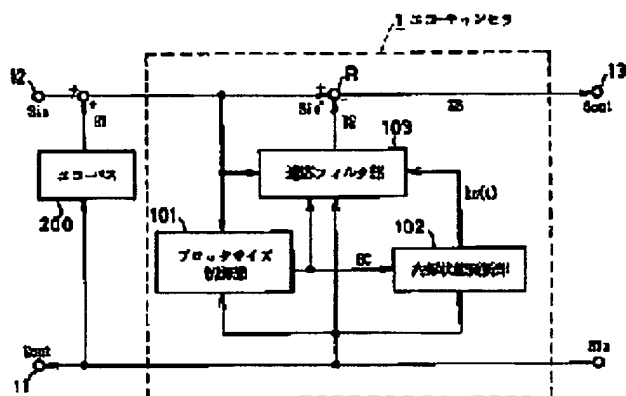
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**Abstract:**

**PROBLEM TO BE SOLVED:** To reduce the arithmetic operation volume at initial stage of convergence by providing an adaptive filter part to generate a false echo signal, an inner state updating part, a block size control part to sequentially output to the adaptive filter part and an adder. **SOLUTION:** A far end input signal  $R_{in}$  and a near end input signal  $S_{in}$  are monitored by the block size control part 101 and an operation mode is decided from a relation between both signals. When initialization is performed, a tap number control signal  $BC$  whose value from the control part 101 shows 1 is outputted to an inner state updating part 102 and the adaptive filter part 103. The updating part 102 forms a gain vector and an inner state variable matrix at current time by a specified equation and a tap coefficient vector at current time in the filter part 103. And the false echo signal  $ER$  at current time is formed by the specific equation in the filter part 103 and an echo cancellation is performed in the adder  $R$  by subtracting the false echo signal  $ER$ .



### JPO Machine translation abstract:

#### (57) Abstract

**SUBJECT** The operation amount at the time of initialization of adaptive operations is reduced. A tap coefficient is more quickly completed as the transfer characteristic of an echo path.

**Means for Solution** An input signal of a near end and a far edge, and an adaptation filter part which generates a false echo signal after presuming the transfer characteristic of an echo path from internal state quantity, The above-mentioned internal state quantity which has the number of elements required in order to presume the transfer characteristic of an echo path sequentially which becomes settled according to tap numbers is initialized, and it has an internal state updating section which updates internal state quantity, expanding the number of elements of internal state quantity one by one according to increase of tap numbers. When judging whether the echo canceller concerned is initialized and initializing, Set tap numbers as an initial value and expand tap numbers one by one after that, and the value is kept constant after tap numbers reach a number set up beforehand, It has a block size control section which outputs tap numbers which change in this way to an internal state updating section and an adaptation filter part, and an adding machine which subtracts a false echo signal from a near end input signal.

### Claim(s)

**Claim 1** An echo canceller comprising:

A near end input signal with which it is superimposed on an echo.

An far-end input signal only for tap numbers.

An adaptation filter part which presumes the transfer characteristic of an echo path in the time from internal state quantity, and generates a false echo signal by convolution arithmetic operation of the point estimate and the above-mentioned far-end input signal.

An internal state updating section which updates the above-mentioned internal state quantity which has the number of elements required in order to presume the transfer characteristic of an echo path sequentially which becomes settled according to tap numbers, and outputs updated

internal state quantity to the above-mentioned adaptation filter part, Judge whether the echo canceller concerned is initialized, and when initializing, Set tap numbers as an initial value and expand tap numbers one by one after that, and the value is kept constant after tap numbers reach a number set up beforehand, An adding machine which subtracts a block size control section which outputs tap numbers which change in this way one by one to the above-mentioned internal state updating section and the above-mentioned adaptation filter part, and a false echo signal outputted by the above-mentioned adaptation filter part from a near end input signal.

**Claim 2** The echo canceller according to claim 1 which the above-mentioned adaptation filter part presumes the transfer characteristic of an echo path in accordance with an iterative least square technique, and is characterized by the above-mentioned internal state updating section updating internal state quantity in accordance with an iterative least square technique.

## Detailed Description of the Invention

### 0001

**Field of the Invention** This invention relates to an echo canceller.

### 0002

**Description of the Prior Art** Generally for the circuit echo suppressor produced in the hybrid circuit in the transmission equipment which accommodated the international circuit etc., an echo canceller is used. The erasing quality of this echo canceller deteriorates by change of the transfer characteristic of an echo path, etc. For this reason, an adaptation filter with the good convergence characteristic which follows change of the transfer characteristic of an echo path at high speed, and generates a false echo signal is needed.

**0003** RLS (recursive least squares: successive-minima square) shown in the Kalman method or document 1 as a computational algorithm for such the convergence characteristic to realize a good adaptation filter -- there are law etc.

**0004** Document 1 "Akira Sakai, "centering on the trend-RLS method of the latest adaptation algorithm -", 1992, Journal of the Acoustical Society of Japan 48 volume 7 No., and pp.493-500" Tap coefficient  $h'(k)$  (namely,  $h'(0) - h'(p)$ ) such whose an adaptation filter is a point estimate of the transfer characteristic of the echo path from which it is obtained by far-end input signal  $x(n)$  and the RLS method By the convolution arithmetic operation shown in (1) type. False echo signal  $y(n)$  is generated. However, in (1) type, as for sigma,  $k$  expresses total from 0 to  $p$  ( $p+1$  is tap numbers), and  $n$  expresses processing time.

### 0005

$y(n) = \sum h'(k) x(n-k) \quad (1)$

**Problem to be solved by the invention** As mentioned above, in order to generate false echo signal  $y(n)$ , with an adaptation filter, tap coefficient  $h'(k)$  which is a point estimate of the transfer characteristic of an echo path is needed. Here, in an adaptation filter, tap numbers must be determined according to the transfer characteristic (characteristic of an impulse response) of an echo path.

**0007** However, since the transfer characteristic of the echo path which is the target of calculation is strange, the length of the impulse response of an echo path may be unable to be specified.

**0008** In that case, although the fixed tap numbers beforehand estimated with a margin which covers the impulse response of an echo path will be used, generation data processing of a false echo signal may be performed by tap numbers longer than sometimes required tap numbers. In especially the initial stage of adaptive operations, although an input signal does not fully exist, the maximum calculation according to fixed tap numbers will be performed, and it sees from the field of computational complexity, and is not efficient.

**0009** Although the high-speed convergence characteristic is shown and converging by repetition calculation of the less than twice of tap numbers is known, the repeat frequency for convergence also increases according to it, and, as a result, the RLS method must do a lot of operation, if the tap numbers of an adaptation filter become long.

**0010** Therefore, in an initial stage of adaptive operations, to attain increase in efficiency of calculation for generation of a false echo signal is desired.

**0011**

**Means for solving problem** This invention is characterized by an echo canceller comprising the following, in order to solve this SUBJECT.

(1) A near end input signal with which it is superimposed on an echo.

An far-end input signal only for tap numbers.

An adaptation filter part which presumes the transfer characteristic of an echo path in the time from internal state quantity, and generates a false echo signal by convolution arithmetic operation of the point estimate and far-end input signal.

(2) An internal state updating section which updates internal state quantity which has the number of elements required in order to presume the transfer characteristic of an echo path sequentially which becomes settled according to tap numbers, and outputs updated internal state quantity to an adaptation filter part, (3) Judge whether the echo canceller concerned is initialized, and when initializing, Set tap numbers as an initial value and expand tap numbers one by one after that, and the value is kept constant after tap numbers reach a number set up beforehand, A block size control section which outputs tap numbers which change in this way one by one to an internal state updating section and an adaptation filter part, and (4) Adding machine which subtracts from a near end input signal a false echo signal outputted from an adaptation filter part

**0012** By such composition, the operation amount at the time of the convergence operation first stage at the time of initializing an adaptation filter part can be reduced, and the high-speed convergence characteristic can be realized.

**0013**

**Mode for carrying out the invention** Hereafter, one embodiment of the echo canceller by this invention is explained in full detail, referring to Drawings.

**0014** The RLS method is used for this embodiment as an updating algorithm of the point estimate of the transfer characteristic of an echo path. So, below, the theoretic updating method of various kinds of values by the RLS method is explained first.

**0015** If ER is made into the false echo signal (echo replica) which is an output of an adaptation filter, false echo signal ER in the time  $t$ , (2) As shown in a formula, it is obtained by the convolution arithmetic operation of far-end input signal vector  $x_n(t)$  and tap coefficient vector  $h'_n(t)$  which is the point estimates of the transfer characteristic of an echo path. However,  $h'_n(t)$  is a  $n$  vector (column vector) in the time  $t$ , and  $x_n(t)$  is a column vector which consists of the time  $t$  with the sampled value of the far-end input signal by the  $n$  past.  $n$  is tap numbers of an adaptation filter part, and in the case of this embodiment, it has the feature for this tap-numbers  $n$  to change so that it may mention later.

**0016****Mathematical formula 1**

For drawings please refer to the original document.

In the RLS method, tap coefficient vector  $h'_n(t)$  which is a point estimate of the transfer characteristic of an echo path in the time  $t$ , Near end input signal **in the time  $t$**  (scalar quantity)  $y(t)$ , and  $n$  dimension gain vector (column vector)  $k_n$  **in the time  $t$**  ( $t$ ), It is updated by a recurrence formula showing with far-end input signal vector  $x_n(t)$  in tap coefficient vector  $h'(3)$  from  $n(t-1)$  type in the time  $t-1$ .

**0017****Mathematical formula 2**

For drawings please refer to the original document.

Here  $n$  dimension gain vector  $k_n$  **in the time  $t$**  ( $t$ ), (4) As shown in a formula, it is sequentially updated by the oblivion coefficient (scalar quantity)  $\lambda$  for making it influence it small as

internal state variable procession  $P_n(t-1)$  of  $n$  dimension in the time  $t-1$ , far-end input signal vector  $x_n(t)$ , and the past information.

**0018**

**Mathematical formula 3**

For drawings please refer to the original document.

Internal state variable procession  $P_n(t)$  in the time  $t$ , (5) As shown in a formula, it is sequentially updated by far-end input signal  $x_n(t)$ , gain vector  $k_n(t)$  in the time  $t$  and state-transition-matrix  $P_n(t-1)$  in the time  $t-1$ , and the recurrence formula using the oblivion coefficient  $\lambda$ .

**0019**

**Mathematical formula 4**

For drawings please refer to the original document.

As mentioned above, in **so that clearly** the RLS method, If the time  $t$  is updated, gain vector  $k_n(t)$  will be updated according to (4) types, After updating tap coefficient vector  $h'_n(t)$  according to (3) types using updated gain vector  $k_n(t)$ , according to (2) types, false echo signal ER of the time  $t$  concerned is formed using this updated tap coefficient vector  $h'_n(t)$ . Internal state variable procession  $P_n(t)$  required for the renewal of gain vector  $k_n(t)$  in the next time is updated according to (5) types.

**0020** Here, the vector and procession of the various kinds currently used by the (2) type - (5) formula mentioned above have a dimension which becomes settled in tap-numbers  $n$  of an adaptation filter part.

**0021** In immediately after **at the time of redo of adaptive operations which in any cases are later mentioned in this embodiment although it was immobilization**, in the former, tap-numbers  $n$  of an adaptation filter part is made to carry out renewal of gradual increase of the tap-numbers  $n$ . Therefore, he is trying to also change various kinds of vectors and the dimension of a procession which are updated suitably according to change of tap-numbers  $n$  by the RLS method.

**0022** In this embodiment, having made it change tap numbers is based on the following views.

**0023** For example, when there is both an far-end input signal and nor a near end input signal neither, tap coefficient vector  $h'_n$  of an adaptation filter part (t) is initialized, and adaptive operations are redone from the beginning. In this case, if various kinds of vectors and the operation of a procession are performed by fixed tap-numbers  $n$  (here, it is considered as  $n=p$ ) like before, even when measurement sizes, such as an far-end input signal, will be less than  $p$ , the operation about the vector and procession of  $p$  dimension is performed. However, since a measurement size is less than  $p$ , naturally the element which takes the effective value of the vector and procession which are acquired as a result of an operation decreases. Thus, it can be said that it has much futility that they perform the operation of a vector or a procession as a dimension according to tap numbers although there are few elements which take an effective value. For example, in internal state variable procession  $P_n(t)$ , there is an element of the square of tap-numbers  $p$ , although the operation according to this number of elements is required, immediately after initialization which redoes adaptive operations from the beginning, there are few elements of an effective value and many element operations are useless.

**0024** So, at this embodiment, reduction of the operation amount is aimed at by expanding tap-numbers  $n$  used by an adaptation filter part one by one according to the effective measurement size after initialization, in redoing adaptive operations from the beginning.

**0025** Drawing 1 is a block diagram showing the functional composition of the echo canceller of the embodiment made according to the above views.

**0026** In drawing 1, the far-end input signal  $R_{in}$  inputted into the far-end input terminal 10 is inputted into the echo canceller 1 of this embodiment, and passes the echo canceller 1 and is given

to the processing circuit of the next step from the output terminal 11. It leaks and appears in the transmission line of the near end input signal  $S_{in}$  inputted from the near end input terminal 12 as echo ET via the echo path (it becomes by a hybrid circuit and others) 200, and the far-end input signal  $R_{out}$  ( $R_{in}$ ) which passed the echo canceller 1 is superimposed by the near end input signal  $S_{in}$ . Near end input signal  $S_{in}'$  superimposed on such echo ET is inputted into the echo canceller 1 of this embodiment, an echo is eliminated, and the near end input signal  $S_{out}$  after elimination (residual signal ZS) is outputted from the terminal 13.

**0027**The echo canceller 1 of the embodiment in the above input/output relation serves as the block size control section 101, the internal state updating section 102, and the adaptation filter part 103 from the adding machine R.

**0028**The adaptation filter part 103 Near end input signal  $S_{in}' (=y(n))$  of the current time  $t$ , Far-end input signal vector  $x_n(t)$  which becomes with the sampled value of the tap-numbers part  $p$  of the far-end input signal  $R_{in}$ , According to the tap coefficient vector  $h'(3)$  mentioned above from  $n(t-1)$  type of direct previous time, Tap coefficient vector  $h'_n$  of the current time  $t$  ( $t$ ) is formed (presuming the transfer characteristic of an echo path), and false echo signal ER is generated according to (2) types from the tap coefficient vector  $h'_n(t)$  and far-end input signal vector  $x_n(t)$ .

**0029**From the block size control section 101, tap-numbers control signal BC ( $=n$ ) is given to this adaptation filter part 103, and it is made as **generate / tap coefficient vector  $h'_n$  of a dimension / (t) according to tap-numbers control signal BC ( $=n$ )** so that it may mention later. Here, when increasing a dimension, it is based on (8) types mentioned later.

**0030**The far-end input signal  $R_{in}$  (far-end input signal vector  $x_n(t)$  which becomes with the sampled value of the tap-numbers part  $n$ ) is inputted into the internal state updating section 102, and This far-end input signal vector  $x_n(t)$ , From internal state variable procession  $P_n(t-1)$  and the oblivion coefficient (scalar quantity)  $\lambda$  in the direct previous time  $t-1$  which is carrying out internal possession. According to a formula, form gain vector  $k_n$  in the current time  $t$  ( $t$ ), and (4) Far-end input signal vector  $x_n(t)$ , According to the oblivion coefficient  $\lambda$  to updated gain vector  $k_n(t)$ , state-transition-matrix  $P_n(t-1)$  in the direct previous time  $t-1$ , and (5) types, internal state variable procession  $P_n(t)$  in the current time  $t$  is formed. Internal possession of the gain vector  $k_n$  in the formed current time  $t$  ( $t$ ) and internal state variable procession  $P_n(t)$  is carried out at the internal state updating section 102 concerned, and gain vector  $k_n(t)$  is given to the adaptation filter part 103.

**0031**So that it may mention later also to this internal state updating section 102 from the block size control section 101. Tap-numbers control signal BC ( $=n$ ) is given, and it is made as **generate / gain vector  $k_n$  of a dimension / (t) according to tap-numbers control signal BC ( $=n$ ), and internal state variable procession  $P_n(t)$** . Here, when increasing the dimension of internal state variable procession  $P_n(t)$ , it is based on (7) types mentioned later. Increase of the dimension of internal state variable procession  $P_n(t)$  and the dimension of far-end input signal vector  $x_n(t)$  will increase the dimension of gain vector  $k_n(t)$ .

**0032**The block size control section 101 judges whether far-end input signal  $R_{in}$  needs to reach, or it is necessary to initialize the echo canceller 1 concerned from the input state of near end input signal  $S_{in}'$  (in other words.). Various kinds of vector and procession  $h'_n(t)$   $k_n(t)$  Judge the stage to initialize  $P_n(t)$ , and when it is necessary to initialize, After making one initialize tap-numbers control signal BC ( $=n$ ) which specifies tap numbers, Whenever the time  $t$  is updated, tap-numbers control signal BC is \*\*\*\*\*ed one time, and after tap-numbers control signal BC reaches maximum tap-numbers  $p$  set up beforehand, even if time passes, maximum tap-numbers  $p$  is made to maintain the value of tap-numbers control signal BC. As mentioned above, tap-numbers control signal BC updated with progress of time immediately after initialization is outputted to the internal state updating section 102 and the adaptation filter part 101.

**0033**The adding machine R subtracts false echo signal ER from the adaptation filter part 103, and eliminates an echo from near end input signal  $S_{in}'$  superimposed on echo ET.

**0034** Every time the echo canceller 1 of this embodiment that consists of above each part lets the whole pass, as shown in the flow chart of drawing 2, it operates. The processing loop in drawing 2 is processed once at each time.

**0035** If the new time  $t$  comes, first, the far-end input signal  $R_{in}$  and near end input signal  $S_{in}'$  will be supervised by the block size control section 101, and operational mode will be judged from both relation, for example (Step S1). For example, it is judged whether the adaptive operations which generate false echo signal ER are initialized by whether it is in the situation (situation where a sound level is not reached) where the fixed time input of either an far-end input signal and a near end input signal or both signals is not carried out.

**0036** In initializing, from the block size control section 101, it is outputted to the internal state updating section 102 and the adaptation filter part 103 by tap-numbers control signal BC ( $=n$ ) whose value is 1, and At this time. The internal state updating section 102 sets internal state variable procession  $P_n(t-1)$  of the direct previous time  $t-1$  as the procession of  $1 \times 1$  which has only initial parameter alpha (fixed value), as shown in (6) types (Step S2).

**0037**

$P_n(t-1) = \alpha$  -- When the result that initialization is unnecessary is obtained by (6), on the other hand judgment of Step S1, the block size control section 101, Check whether old tap-numbers control signal BC ( $=n$ ) has already reached maximum tap-numbers  $p$ , and if it has not reached, If tap-numbers control signal BC ( $=n$ ) which \*\*\*\*\*ed one time was outputted to the internal state updating section 102 and the adaptation filter part 103, expanding processing of the dimension was performed and maximum tap-numbers  $p$  is reached on the other hand, Tap-numbers control signal BC ( $=n$ ) of maximum tap-numbers  $p$  is outputted to the internal state updating section 102 and the adaptation filter part 103, and it is made not to make the expanding processing of a dimension perform (Step S3).

**0038** The internal state updating section 102 to which tap-numbers control signal BC ( $=n$ ) which it \*\*\*\*\*ed one time was given here, According to (7) types, internal state variable procession  $P_n(t-1)$  of the direct previous time  $t-1$ , According to (8) types, as for the adaptation filter part 103 to which tap-numbers control signal BC ( $=n$ ) by which the dimension updated in procession only with 1 **large**, and it \*\*\*\*\*ed it one time was given, a dimension updates tap coefficient vector  $h'_n(t-1)$  of the direct previous time  $t-1$  in procession only with 1

**large .**

**0039**

**Mathematical formula 5**

For drawings please refer to the original document.

Then, according to (4) types and (5) types which were mentioned above, gain vector  $k_n$  in the current time  $t$  ( $t$ ) and internal state variable procession  $P_n(t)$  is formed of the internal state updating section 102 regardless of the existence of execution of expansion operation of a dimension (step S4). Then, in the adaptation filter part 103, tap coefficient vector  $h'_n$  in the current time  $t$  ( $t$ ) is formed according to (3) types mentioned above (Step S5). Naturally the dimension of far-end input signal vector  $x_n(t)$  used at the time of these data processing is also depended on the value of tap-numbers control signal BC at that time ( $=n$ ).

**0040** And in the adaptation filter part 103, according to (2) types mentioned above, false echo signal ER in the current time  $t$  is formed, and echo suppressor operation by subtraction of false echo signal ER is performed in the adding machine R (Step S6).

**0041** Thus, after a series of processings in the current time  $t$  are completed, it will return to Step S1 and will progress to processing of the next time ( $t=t+1$ ).

**0042** When initialization is needed by processing shown in above drawing 2, Effective tap numbers perform the adaptive operations of 1 (S1, S2, S4-S6), then -- performing the adaptive operations which increased effective tap numbers every 1 for every time until it reached maximum tap-numbers  $p$  (S1 and S3 (accompanied by renewal of tap numbers).) After reaching S4-S6 and maximum tap-numbers  $p$ , the adaptive operations in the tap-numbers  $p$  are performed (S1, S3

(tap numbers are not updated), S4-S6).

**0043** Since it was made to make tap numbers increase from the initialization start time which redoes adaptive operations again one by one about operation of an internal state updating section and an adaptation filter part according to the above-mentioned embodiment, the operation amount at the time of initialization of adaptive operations refollowed to the transfer characteristic of an echo path is reducible.

**0044** When an impulse response of an echo path is comparatively short, even if it reduces an operation amount in this way, a tap coefficient can be more quickly completed as the transfer characteristic of an echo path.

**0045** Various parameters, such as a tap coefficient of an adaptation filter part, can realize prompt convergence operation, without disrupting convergence operation, since it is succeeded to the next time also when tap numbers are increased.

**0046** Although an echo canceller applied to the RLS method was shown in the above-mentioned embodiment, This invention is applicable if it is the echo canceller which has adopted an algorithm which forms a tap coefficient (vector) using internal state quantity which is expressed with a vector which has a dimension according to tap numbers, a procession, etc., and which is updated one by one for every time. For example, this invention is applicable to an echo canceller using the Kalman-filter method, a learning-identification method, etc.

**0047** In the above-mentioned embodiment, although an echo canceller which eliminates an echo by impedance mismatching of a hybrid circuit is assumed, this invention is applicable to an echo canceller which eliminates from a loudspeaker an echo around which it turned to a microphone.

#### **0048**

**Effect of the Invention** As mentioned above, since it was made to make tap numbers increase from the initialization start time which redoes adaptive operations again one by one about operation of an internal state updating section and an adaptation filter part according to this invention, The operation amount at the time of initialization of adaptive operations refollowed to the transfer characteristic of an echo path is reducible, and when the impulse response of an echo path is comparatively short, a tap coefficient can be more quickly completed as the transfer characteristic of an echo path.

**Field of the Invention** This invention relates to an echo canceller.

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#### **0005**

$y(n) = \sum h'(k) x(n-k) \text{ -- (1)}$



**Effect of the Invention**As mentioned above, since it was made to make tap numbers increase from the initialization start time which redoes adaptive operations again one by one about operation of an internal state updating section and an adaptation filter part according to this invention, The operation amount at the time of initialization of adaptive operations reflowed to the transfer characteristic of an echo path is reducible, and when the impulse response of an echo path is comparatively short, a tap coefficient can be more quickly completed as the transfer characteristic of an echo path.

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**Problem to be solved by the invention**As mentioned above, in order to generate false echo signal  $y(n)$ , with an adaptation filter, tap coefficient  $h'(k)$  which is a point estimate of the transfer characteristic of an echo path is needed. Here, in an adaptation filter, tap numbers must be determined according to the transfer characteristic (characteristic of an impulse response) of an echo path.

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**Means for solving problem**This invention is characterized by an echo canceller comprising the following, in order to solve this SUBJECT.

(1) The near end input signal with which it is superimposed on the echo.

The far-end input signal only for tap numbers.

The adaptation filter part which presumes the transfer characteristic of the echo path in the time from internal state quantity, and generates a false echo signal by the convolution arithmetic operation of the point estimate and far-end input signal.

(2) The internal state updating section which updates the internal state quantity which has the number of elements required in order to presume the transfer characteristic of an echo path sequentially which becomes settled according to tap numbers, and outputs the updated internal state quantity to an adaptation filter part, (3) Judge whether the echo canceller concerned is initialized, and when initializing, Set tap numbers as an initial value and expand tap numbers one by one after that, and the value is kept constant after tap numbers reach the number set up beforehand, The block size control section which outputs the tap numbers which change in this way one by one to an internal state updating section and an adaptation filter part, and (4) Adding machine which subtracts from a near end input signal the false echo signal outputted from the adaptation filter part

**0012**By such composition, the operation amount at the time of the convergence operation first stage at the time of initializing an adaptation filter part can be reduced, and the high-speed convergence characteristic can be realized.

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**Mode for carrying out the invention**Hereafter, one embodiment of the echo canceller by this invention is explained in full detail, referring to Drawings.

**0014**The RLS method is used for this embodiment as an updating algorithm of the point estimate of the transfer characteristic of an echo path. So, below, the theoretic updating method of various kinds of values by the RLS method is explained first.

**0015**If ER is made into the false echo signal (echo replica) which is an output of an adaptation filter, false echo signal ER in the time  $t$ , (2) As shown in a formula, it is obtained by the convolution arithmetic operation of far-end input signal vector  $x_n(t)$  and tap coefficient vector  $h'_n(t)$  which is the point estimates of the transfer characteristic of an echo path. However,  $h'_n(t)$  is a  $n$  vector (column vector) in the time  $t$ , and  $x_n(t)$  is a column vector which consists of the time  $t$  with the sampled value of the far-end input signal by the  $n$  past.  $n$  is tap numbers of an adaptation filter part, and in the case of this embodiment, it has the feature for this tap-numbers  $n$  to change so that it may mention later.

**0016**

#### **Mathematical formula 1**

For drawings please refer to the original document.

In the RLS method, tap coefficient vector  $h'_n(t)$  which is a point estimate of the transfer characteristic of the echo path in the time  $t$ , Near end input signal **in the time  $t$**  (scalar quantity)  $y(t)$ , and  $n$  dimension gain vector (column vector)  $k_n$  **in the time  $t$**  (3), It is updated by the recurrence formula showing with far-end input signal vector  $x_n(t)$  in the tap coefficient vector  $h'_n(t)$  from  $n(t-1)$  type in the time  $t-1$ .

**0017**

#### **Mathematical formula 2**

For drawings please refer to the original document.

Here  $n$  dimension gain vector  $k_n$  **in the time  $t$**  (4), (4) As shown in a formula, it is sequentially updated by the oblivion coefficient (scalar quantity)  $\lambda$  for making it influence it small as internal state variable procession  $P_n(t-1)$  of  $n$  dimension in the time  $t-1$ , far-end input signal vector  $x_n(t)$ , and the past information.

**0018**

#### **Mathematical formula 3**

For drawings please refer to the original document.

Internal state variable procession  $P_n(t)$  in the time  $t$ , (5) As shown in a formula, it is sequentially updated by far-end input signal  $x_n(t)$ , gain vector  $k_n(t)$  in the time  $t$  and state-transition-matrix  $P_n(t-1)$  in the time  $t-1$ , and the recurrence formula using the oblivion coefficient  $\lambda$ .

**0019**

#### **Mathematical formula 4**

For drawings please refer to the original document.

As mentioned above, in **so that clearly** the RLS method, If the time  $t$  is updated, gain vector  $k_n(t)$  will be updated according to (4) types, After updating tap coefficient vector  $h'_n(t)$  according to (3) types using updated gain vector  $k_n(t)$ , according to (2) types, false echo signal ER of the time  $t$  concerned is formed using this updated tap coefficient vector  $h'_n(t)$ . Internal state variable procession  $P_n(t)$  required for the renewal of gain vector  $k_n(t)$  in the next time is updated

according to (5) types.

**0020** Here, the vector and procession of the various kinds currently used by the (2) type - (5) formula mentioned above have a dimension which becomes settled in tap-numbers  $n$  of an adaptation filter part.

**0021** In immediately after **at the time of redo of adaptive operations which in any cases are later mentioned in this embodiment although it was immobilization**, in the former, tap-numbers  $n$  of an adaptation filter part is made to carry out renewal of gradual increase of the tap-numbers  $n$ . Therefore, he is trying to also change various kinds of vectors and the dimension of a procession which are updated suitably according to change of tap-numbers  $n$  by the RLS method.

**0022** In this embodiment, having made it change tap numbers is based on the following views.

**0023** For example, when there is both an far-end input signal and nor a near end input signal neither, tap coefficient vector  $h'_n$  **of an adaptation filter part** ( $t$ ) is initialized, and adaptive operations are redone from the beginning. In this case, if various kinds of vectors and the operation of a procession are performed by fixed tap-numbers  $n$  (here, it is considered as  $n=p$ ) like before, even when measurement sizes, such as an far-end input signal, will be less than  $p$ , the operation about the vector and procession of  $p$  dimension is performed. However, since a measurement size is less than  $p$ , naturally the element which takes the effective value of the vector and procession which are acquired as a result of an operation decreases. Thus, it can be said that it has much futility that they perform the operation of a vector or a procession as a dimension according to tap numbers although there are few elements which take an effective value. For example, in internal state variable procession  $P_n(t)$ , there is an element of the square of tap-numbers  $p$ , although the operation according to this number of elements is required, immediately after initialization which redoes adaptive operations from the beginning, there are few elements of an effective value and many element operations are useless.

**0024** So, at this embodiment, reduction of the operation amount is aimed at by expanding tap-numbers  $n$  used by an adaptation filter part one by one according to the effective measurement size after initialization, in redoing adaptive operations from the beginning.

**0025** Drawing 1 is a block diagram showing the functional composition of the echo canceller of the embodiment made according to the above views.

**0026** In drawing 1, the far-end input signal  $R_{in}$  inputted into the far-end input terminal 10 is inputted into the echo canceller 1 of this embodiment, and passes the echo canceller 1 and is given to the processing circuit of the next step from the output terminal 11. It leaks and appears in the transmission line of the near end input signal  $S_{in}$  inputted from the near end input terminal 12 as echo ET via the echo path (it becomes by a hybrid circuit and others) 200, and the far-end input signal  $R_{out}$  ( $R_{in}$ ) which passed the echo canceller 1 is superimposed by the near end input signal  $S_{in}$ . Near end input signal  $S_{in}'$  superimposed on such echo ET is inputted into the echo canceller 1 of this embodiment, an echo is eliminated, and the near end input signal  $S_{out}$  after elimination (residual signal ZS) is outputted from the terminal 13.

**0027** The echo canceller 1 of an embodiment in the above input/output relation serves as the block size control section 101, the internal state updating section 102, and the adaptation filter part 103 from the adding machine R.

**0028** The adaptation filter part 103 Near end input signal  $S_{in}' (=y(n))$  of the current time  $t$ , Far-end input signal vector  $x_n(t)$  which becomes with a sampled value of the tap-numbers part  $p$  of the far-end input signal  $R_{in}$ , According to tap coefficient vector  $h'(3)$  mentioned above from  $n(t-1)$  type of direct previous time, Tap coefficient vector  $h'_n$  **of the current time  $t$**  ( $t$ ) is formed (presuming the transfer characteristic of an echo path), and false echo signal ER is generated according to (2) types from the tap coefficient vector  $h'_n(t)$  and far-end input signal vector  $x_n(t)$ .

**0029** From the block size control section 101, tap-numbers control signal BC ( $=n$ ) is given to this adaptation filter part 103, and it is made as **generate / tap coefficient vector  $h'_n$  of a dimension / (t) according to tap-numbers control signal BC ( $=n$ )** so that it may mention later. Here, when increasing a dimension, it is based on (8) types mentioned later.

**0030** The far-end input signal  $R_{in}$  (far-end input signal vector  $x_n(t)$  which becomes with a sampled value of the tap-numbers part  $n$ ) is inputted into the internal state updating section 102, and This

far-end input signal vector  $x_n(t)$ , From internal state variable procession  $P_n(t-1)$  and the oblivion coefficient (scalar quantity)  $\lambda$  in the direct previous time  $t-1$  which is carrying out internal possession. According to a formula, form gain vector  $k_n$  in the current time  $t(t)$ , and (4) Far-end input signal vector  $x_n(t)$ , According to the oblivion coefficient  $\lambda$  to updated gain vector  $k_n(t)$ , state-transition-matrix  $P_n(t-1)$  in the direct previous time  $t-1$ , and (5) types, internal state variable procession  $P_n(t)$  in the current time  $t$  is formed. Internal possession of the gain vector  $k_n$  in the formed current time  $t(t)$  and internal state variable procession  $P_n(t)$  is carried out at the internal state updating section 102 concerned, and gain vector  $k_n(t)$  is given to the adaptation filter part 103.

**0031** So that it may mention later also to this internal state updating section 102 from the block size control section 101. Tap-numbers control signal  $BC(=n)$  is given, and it is made as **generate / gain vector  $k_n$  / of a dimension / (t) according to tap-numbers control signal  $BC(=n)$ , and internal state variable procession  $P_n(t)$** . Here, when increasing the dimension of internal state variable procession  $P_n(t)$ , it is based on (7) types mentioned later. Increase of the dimension of internal state variable procession  $P_n(t)$  and the dimension of far-end input signal vector  $x_n(t)$  will increase the dimension of gain vector  $k_n(t)$ .

**0032** The block size control section 101 judges whether far-end input signal  $R_{in}$  needs to reach, or it is necessary to initialize the echo canceller 1 concerned from the input state of near end input signal  $S_{in'}$  (in other words.). Various kinds of vector and procession  $h'_n(t)$   $k_n(t)$  Judge the stage to initialize  $P_n(t)$ , and when it is necessary to initialize, After making one initialize tap-numbers control signal  $BC(=n)$  which specifies tap numbers, Whenever the time  $t$  is updated, tap-numbers control signal  $BC$  is \*\*\*\*\*ed one time, and after tap-numbers control signal  $BC$  reaches maximum tap-numbers  $p$  set up beforehand, even if time passes, maximum tap-numbers  $p$  is made to maintain the value of tap-numbers control signal  $BC$ . As mentioned above, tap-numbers control signal  $BC$  updated with progress of time immediately after initialization is outputted to the internal state updating section 102 and the adaptation filter part 101.

**0033** The adding machine  $R$  subtracts false echo signal  $ER$  from the adaptation filter part 103, and eliminates an echo from near end input signal  $S_{in'}$  superimposed on echo  $ET$ .

**0034** Every time the echo canceller 1 of this embodiment that consists of above each part lets the whole pass, as shown in a flow chart of drawing 2, it operates. A processing loop in drawing 2 is processed once at each time.

**0035** If the new time  $t$  comes, first, the far-end input signal  $R_{in}$  and near end input signal  $S_{in'}$  will be supervised by the block size control section 101, and operational mode will be judged from both relation, for example (Step S1). For example, it is judged whether adaptive operations which generate false echo signal  $ER$  are initialized by whether it is in a situation (situation where a sound level is not reached) where the fixed time input of either an far-end input signal and a near end input signal or both signals is not carried out.

**0036** In initializing, from the block size control section 101, it is outputted to the internal state updating section 102 and the adaptation filter part 103 by tap-numbers control signal  $BC(=n)$  whose value is 1, and At this time. The internal state updating section 102 sets internal state variable procession  $P_n(t-1)$  of the direct previous time  $t-1$  as the procession of  $1 \times 1$  which has only initial parameter  $\alpha$  (fixed value), as shown in (6) types (Step S2).

**0037**

$P_n(t-1) = \alpha$  -- When the result that initialization is unnecessary is obtained by (6), on the other hand judgment of Step S1, the block size control section 101, Check whether old tap-numbers control signal  $BC(=n)$  has already reached maximum tap-numbers  $p$ , and if it has not reached, If tap-numbers control signal  $BC(=n)$  which \*\*\*\*\*ed one time was outputted to the internal state updating section 102 and the adaptation filter part 103, expanding processing of the dimension was performed and maximum tap-numbers  $p$  is reached on the other hand, Tap-numbers control signal  $BC(=n)$  of maximum tap-numbers  $p$  is outputted to the internal state updating section 102 and the adaptation filter part 103, and it is made not to make the expanding

processing of a dimension perform (Step S3).

**0038**The internal state updating section 102 to which tap-numbers control signal BC (=n) which it \*\*\*\*\*ed one time was given here, According to (7) types, internal state variable procession  $P_n(t-1)$  of the direct previous time t-1, According to (8) types, as for the adaptation filter part 103 to which tap-numbers control signal BC (=n) by which the dimension updated in procession only with 1 **large** , and it \*\*\*\*\*ed it one time was given, a dimension updates tap coefficient vector  $h'_n(t-1)$  of the direct previous time t-1 in procession only with 1 **large** .

**0039**

#### **Mathematical formula 5**

For drawings please refer to the original document.

Then, according to (4) types and (5) types which were mentioned above, gain vector  $k_n$  in the current time t (t) and internal state variable procession  $P_n(t)$  is formed of the internal state updating section 102 regardless of the existence of execution of expansion operation of a dimension (step S4). Then, in the adaptation filter part 103, tap coefficient vector  $h'_n$  in the current time t (t) is formed according to (3) types mentioned above (Step S5). Naturally the dimension of far-end input signal vector  $x_n(t)$  used at the time of these data processing is also depended on the value of tap-numbers control signal BC at that time (=n).

**0040**And in the adaptation filter part 103, according to (2) types mentioned above, false echo signal ER in the current time t is formed, and echo suppressor operation by subtraction of false echo signal ER is performed in the adding machine R (Step S6).

**0041**Thus, after a series of processings in the current time t are completed, it will return to Step S1 and will progress to processing of the next time ( $t=t+1$ ).

**0042**When initialization is needed by processing shown in above drawing 2, Effective tap numbers perform the adaptive operations of 1 (S1, S2, S4-S6), then -- performing the adaptive operations which increased effective tap numbers every 1 for every time until it reached maximum tap-numbers p (S1 and S3 (accompanied by renewal of tap numbers).) After reaching S4-S6 and maximum tap-numbers p, the adaptive operations in the tap-numbers p are performed (S1, S3 (tap numbers are not updated), S4-S6).

**0043**Since it was made to make tap numbers increase from the initialization start time which redoes adaptive operations again one by one about operation of an internal state updating section and an adaptation filter part according to the above-mentioned embodiment, the operation amount at the time of initialization of adaptive operations refollowed to the transfer characteristic of an echo path is reducible.

**0044**When the impulse response of an echo path is comparatively short, even if it reduces an operation amount in this way, a tap coefficient can be more quickly completed as the transfer characteristic of an echo path.

**0045**Various parameters, such as a tap coefficient of an adaptation filter part, can realize prompt convergence operation, without disrupting convergence operation, since it is succeeded to the next time also when tap numbers are increased.

**0046**Although the echo canceller applied to the RLS method was shown in the above-mentioned embodiment, This invention is applicable if it is the echo canceller which has adopted the algorithm which forms a tap coefficient (vector) using the internal state quantity which is expressed with the vector which has a dimension according to tap numbers, a procession, etc., and which is updated one by one for every time. For example, this invention is applicable to the echo canceller using the Kalman-filter method, a learning-identification method, etc.

**0047**In the above-mentioned embodiment, although the echo canceller which eliminates the echo by the impedance mismatching of a hybrid circuit is assumed, this invention is applicable to the echo canceller which eliminates from a loudspeaker the echo around which it turned to the microphone.

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**Brief Description of the Drawings**

**Drawing 1** It is a functional block diagram showing the composition of an embodiment.

**Drawing 2** It is the flow chart which showed operation of the embodiment.

**Explanations of letters or numerals**

1 -- **An adaptation filter part, R / -- Adding machine.** -- An echo canceller, 101 -- A block size control section, 102 -- An internal state updating section, 103

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**Drawing 1**

For drawings please refer to the original document.

**Drawing 2**

For drawings please refer to the original document.

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For drawings please refer to the original document.

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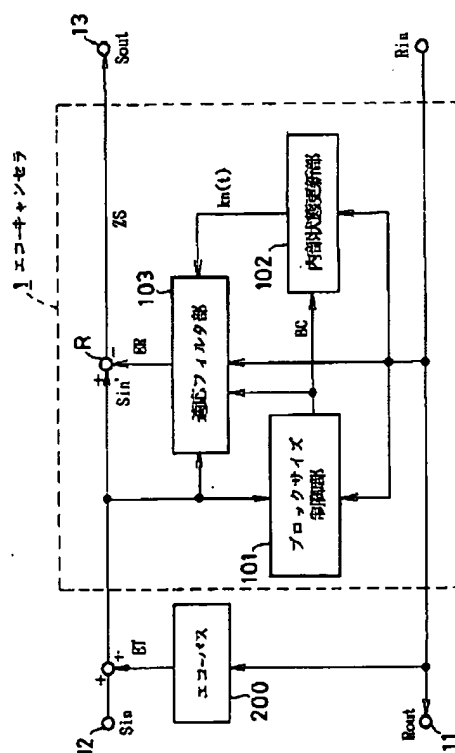
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(54) 【発明の名称】 エコーキャンセラ

(57) 【要約】

【課題】 適応動作の初期化時における演算量を削減する。タップ係数をより速くエコーパスの伝達特性に収束させる。

【解決手段】 近端及び遠端の入力信号と、内部状態量とからエコーパスの伝達特性を推定した後、疑似エコー信号を生成する適応フィルタ部と、エコーパスの伝達特性を逐次的に推定するために必要な、タップ数に応じて定まる要素数を有する上記内部状態量を初期化し、タップ数の増大に応じて内部状態量の要素数を逐次拡大しつつ内部状態量を更新する内部状態更新部とを有する。また、当該エコーキャンセラを初期化するか否かを判断し、初期化する場合に、タップ数を初期値に設定し、その後タップ数を逐次拡大し、予め設定された数にタップ数が達した後はその値を一定に保ち、このように変化するタップ数を内部状態更新部及び適応フィルタ部へ出力するブロックサイズ制御部と、近端入力信号から疑似エコー信号を減算する加算器とを有する。



## 【特許請求の範囲】

【請求項1】 エコーが重畳されている近端入力信号と、タップ数分だけの遠端入力信号と、内部状態量とからその時刻におけるエコーパスの伝達特性を推定し、その推定値と上記遠端入力信号との畳み込み演算によって疑似エコー信号を生成する適応フィルタ部と、エコーパスの伝達特性を逐次的に推定するために必要な、タップ数に応じて定まる要素数を有する上記内部状態量を更新し、更新された内部状態量を上記適応フィルタ部へ出力する内部状態更新部と、当該エコーキャンセラを初期化するか否かを判断し、初期化する場合に、タップ数を初期値に設定し、その後タップ数を逐次拡大し、予め設定された数にタップ数が達した後はその値を一定に保ち、このように変化するタップ数を上記内部状態更新部及び上記適応フィルタ部へ逐次出力するブロックサイズ制御部と、近端入力信号から上記適応フィルタ部から出力された疑似エコー信号を減算する加算器とを有することを特徴とするエコーキャンセラ。

【請求項2】 上記適応フィルタ部が、エコーパスの伝達特性を逐次最小2乗法に従って推定すると共に、上記内部状態更新部が、逐次最小2乗法に従って内部状態量を更新することを特徴とする請求項1に記載のエコーキャンセラ。

## 【発明の詳細な説明】

【0001】

$$y(n) = \sum h'(k) x(n-k)$$

【0006】

【発明が解決しようとする課題】 以上のように、疑似エコー信号  $y(n)$  を発生させるために、適応フィルタではエコーパスの伝達特性の推定値であるタップ係数  $h'(k)$  が必要となる。ここで、適応フィルタでは、エコーパスの伝達特性（インパルス応答の特性）に応じてタップ数を決定しなければならない。

【0007】 しかし、計算の対象となるエコーパスの伝達特性は未知なので、エコーパスのインパルス応答の長さが特定できない場合がある。

【0008】 その場合、エコーパスのインパルス応答をカバーするような余裕をもって予め見積もった固定的なタップ数を利用することになるが、時として必要なタップ数よりも長いタップ数で、疑似エコー信号の生成演算処理が行なわれる可能性がある。特に適応動作の初期段階においては、入力信号が十分に存在しないにもかかわらず、固定タップ数に応じた最大限の計算を行なうことになり、計算量の面から見て効率的でない。

【0009】 また、RLS法は、高速な収束特性を示し、タップ数の2倍以内の繰り返し計算で収束することが知られているが、適応フィルタのタップ数が長くなると、それに伴って収束のための繰り返し回数も増大し、その結果、大量の演算をしなければならなくなる。

【発明の属する技術分野】 本発明は、エコーキャンセラに関するものである。

【0002】

【従来の技術】 国際回線などを収容した伝送装置におけるハイブリッド回路で生ずる回線エコー除去のために、一般にはエコーキャンセラが用いられる。このエコーキャンセラの消去特性は、エコーパスの伝達特性の変動などによって劣化する。このため、エコーパスの伝達特性の変動に高速に追従して疑似エコー信号を生成する収束特性が良好な適応フィルタが必要となる。

【0003】 このような収束特性が良好な適応フィルタを実現するための計算アルゴリズムとして、カルマン法や文献1に示すRLS (recursive least squares: 逐次最小2乗) 法などがある。

【0004】 文献1『酒井著、「最近の適応アルゴリズムの動向—RLS法を中心として—」、1992、日本音響学会誌48巻7号、pp.493-500』

このような適応フィルタは、遠端入力信号  $x(n)$  と、RLS法によって得られるエコーパスの伝達特性の推定値であるタップ係数  $h'(k)$  (すなわち  $h'(0) \sim h'(p)$ ) との(1)式に示す畳み込み演算によって、疑似エコー信号  $y(n)$  を生成するものである。但し、(1)式において、 $\Sigma$ は  $k$  が0から  $p$  ( $p+1$ がタップ数)までの総和を表しており、 $n$ は処理時刻を表している。

【0005】

$$\cdots(1)$$

【0010】 そのため、適応動作の初期段階において、疑似エコー信号の生成のための計算の効率化を図ることが望まれている。

【0011】

【課題を解決するための手段】 かかる課題を解決するために、本発明のエコーキャンセラは、(1) エコーが重畳されている近端入力信号と、タップ数分だけの遠端入力信号と、内部状態量とからその時刻におけるエコーパスの伝達特性を推定し、その推定値と遠端入力信号との畳み込み演算によって疑似エコー信号を生成する適応フィルタ部と、(2) エコーパスの伝達特性を逐次的に推定するために必要な、タップ数に応じて定まる要素数を有する内部状態量を更新し、更新された内部状態量を適応フィルタ部へ出力する内部状態更新部と、(3) 当該エコーキャンセラを初期化するか否かを判断し、初期化する場合に、タップ数を初期値に設定し、その後タップ数を逐次拡大し、予め設定された数にタップ数が達した後はその値を一定に保ち、このように変化するタップ数を内部状態更新部及び適応フィルタ部へ逐次出力するブロックサイズ制御部と、(4) 近端入力信号から適応フィルタ部から出力された疑似エコー信号を減算する加算器とを有することを特徴とする。

【0012】 このような構成により、適応フィルタ部を



初期化した際の収束動作初期時の演算量を削減でき、高速な収束特性を実現できる。

【0013】

【発明の実施の形態】以下、本発明によるエコーキャンセラの一実施形態を図面を参照しながら詳述する。

【0014】この実施形態は、エコーパスの伝達特性の推定値の更新アルゴリズムとしてRLS法を用いたものである。そこで、以下ではまず、RLS法による各種の値の原理的な更新方法を説明する。

【0015】ERを適応フィルタの出力である疑似エコー信号（エコーレプリカ）とすると、時刻 $t$ における疑似エコー信号ERは、(2)式に示すように、遠端入力信

$$ER = h'^T(t) x_n(t)$$

RLS法においては、時刻 $t$ におけるエコーパスの伝達特性の推定値であるタップ係数ベクトル $h'_n(t)$ は、時刻 $t$ での近端入力信号（スカラー量） $y(t)$ と、時刻 $t$ での $n$ 次元ゲインベクトル（縦ベクトル） $k_n(t)$ と、遠端入力信号ベクトル $x_n(t)$ と、時刻 $t-1$ での

$$h'_n(t) = h'_n(t-1) + k_n(t)(y(t) - x_n^T(t)h'_n(t-1)) \quad \text{--- (3)}$$

ここで、時刻 $t$ での $n$ 次元ゲインベクトル $k_n(t)$ は、(4)式に示すように、時刻 $t-1$ における $n$ 次元の内部状態変数行列 $P_n(t-1)$ と、遠端入力信号ベクトル $x_n(t)$ と、過去の情報ほど影響を小さくさせるための忘却

$$k_n(t) = \frac{P_n(t-1)x_n(t)}{\lambda + x_n^T(t)P_n(t-1)x_n(t)} \quad \text{--- (4)}$$

また、時刻 $t$ における内部状態変数行列 $P_n(t)$ は、(5)式に示すように、遠端入力信号 $x_n(t)$ と、時刻 $t$ におけるゲインベクトル $k_n(t)$ と、時刻 $t-1$ における状態遷移行列 $P_n(t-1)$ と、忘却係数 $\lambda$ を用いた漸化

$$P_n(t) = \frac{1}{\lambda} (P_n(t-1) - k_n(t)x_n^T(t)P_n(t-1)) \quad \text{--- (5)}$$

以上から明らかなように、RLS法においては、時刻 $t$ が更新されると、(4)式に従って、ゲインベクトル $k_n(t)$ を更新し、更新されたゲインベクトル $k_n(t)$ をも用いて、(3)式に従って、タップ係数ベクトル $h'_n(t)$ を更新した後、この更新されたタップ係数ベクトル $h'_n(t)$ をも用いて、(2)式に従って、当該時刻 $t$ の疑似エコー信号ERを形成する。また、次の時刻におけるゲインベクトル $k_n(t)$ の更新に必要な内部状態変数行列 $P_n(t)$ を(5)式に従って更新しておく。

【0020】ここで、上述した(2)式～(5)式で使用されている各種のベクトルや行列は、適応フィルタ部のタップ数 $n$ で定まる次元を有するものである。

【0021】従来においては、適応フィルタ部のタップ数 $n$ はいかなる場合にも固定であったが、この実施形態においては、後述するような適応動作のやり直し時の直後の場合には、タップ数 $n$ を漸増更新させるようにして

号ベクトル $x_n(t)$ と、エコーパスの伝達特性の推定値であるタップ係数ベクトル $h'_n(t)$ との畳み込み演算によって得られる。但し、 $h'_n(t)$ は時刻 $t$ における $n$ 次元ベクトル（縦ベクトル）であり、 $x_n(t)$ は時刻 $t$ から過去 $n$ 個までの遠端入力信号のサンプル値でなる縦ベクトルである。また、 $n$ は、適応フィルタ部のタップ数であり、この実施形態の場合、後述するように、このタップ数 $n$ が変化することに特徴を有するものである。

【0016】

【数1】

--- (2)

タップ係数ベクトル $h'_n(t-1)$ とから、(3)式に示す漸化式によって更新されるものである。

【0017】

【数2】

係数（スカラー量） $\lambda$ によって逐次的に更新されるものである。

【0018】

【数3】

式によって逐次的に更新されるものである。

【0019】

【数4】

いる。従って、RLS法によって適宜更新される各種のベクトルや行列の次元も、タップ数 $n$ の変化に応じて変化させるようにしている。

【0022】この実施形態において、タップ数を変化させるようにしたのは、以下の考え方による。

【0023】例えば、遠端入力信号や近端入力信号が共にはないような場合には、適応フィルタ部のタップ係数ベクトル $h'_n(t)$ を初期化して適応動作を最初からやり直す。この場合において、従来のように、固定タップ数 $n$ （ここでは $n=p$ とする）で各種のベクトルや行列の演算を行なうと、遠端入力信号等のサンプル数が $p$ に満たない場合でも、 $p$ 次元のベクトルや行列についての演算を行なう。しかし、サンプル数が $p$ に満たないので、演算の結果得られるベクトルや行列の有効な値をとる要素は当然に少なくなる。このように有効な値をとる要素が、少ないにも拘らず、タップ数に応じた次元として、

ベクトルや行列の演算を行なうことは無駄が多いといふことができる。例えば、内部状態変数行列 $P_n(t)$ では、タップ数 $p$ の2乗の要素があり、この要素数に応じた演算が必要であるが、適応動作を最初からやり直す初期化直後においては、有効な値の要素が少なく、多くの要素演算が無駄になっている。

【0024】そこで、この実施形態では、適応フィルタ部で用いるタップ数 $n$ を、適応動作を最初からやり直す場合には、初期化後の有効サンプル数に応じて順次拡大するようにすることで演算量の削減を図っている。

【0025】図1は、以上のような考え方に従ってなされた実施形態のエコーキャンセラの機能的構成を示すブロック図である。

【0026】図1において、遠端入力端子10に入力された遠端入力信号 $R_{in}$ は、この実施形態のエコーキャンセラ1に入力されると共に、エコーキャンセラ1を通過して出力端子11から次段の処理回路に与えられる。エコーキャンセラ1を通過した遠端入力信号 $R_{out}$  ( $R_{in}$ )は、エコーパス(ハイブリッド回路その他でなる)200を介して、エコーETとして、近端入力端子12から入力された近端入力信号 $S_{in}$ の伝送ラインに漏れでて、近端入力信号 $S_{in}$ に重畳される。このようなエコーETが重畳された近端入力信号 $S_{in}'$ が、この実施形態のエコーキャンセラ1に入力されてエコーが消去され、消去後の近端入力信号 $S_{out}$ (残差信号ZS)が端子13から出力される。

【0027】以上のような入出力関係にある実施形態のエコーキャンセラ1は、ブロックサイズ制御部101と、内部状態更新部102と、適応フィルタ部103と、加算器Rとからなる。

【0028】適応フィルタ部103は、現時刻 $t$ の近端入力信号 $S_{in}' (=y(n))$ と、遠端入力信号 $R_{in}$ のタップ数分 $p$ だけのサンプル値でなる遠端入力信号ベクトル $x_n(t)$ と、直前時刻のタップ係数ベクトル $h'_n(t-1)$ とから、上述した(3)式に従って、現時刻 $t$ のタップ係数ベクトル $h'_n(t)$ を形成し(エコーパスの伝達特性を推定し)、そのタップ係数ベクトル $h'_n(t)$ と、遠端入力信号ベクトル $x_n(t)$ とから、(2)式に従って、疑似エコー信号ERを生成するものである。

【0029】なお、この適応フィルタ部103には、後述するように、ブロックサイズ制御部101から、タップ数制御信号 $BC (=n)$ が与えられており、タップ数制御信号 $BC (=n)$ に応じた次元のタップ係数ベクトル $h'_n(t)$ を生成するようになされている。ここで、次元を増大させる場合は、後述する(8)式による。

【0030】内部状態更新部102には、遠端入力信号 $R_{in}$ (タップ数分 $n$ だけのサンプル値でなる遠端入力信号ベクトル $x_n(t)$ )が入力されており、この遠端入力信号ベクトル $x_n(t)$ と、内部保有している直前時刻

$t-1$ における内部状態変数行列 $P_n(t-1)$ 及び忘却係数(スカラー量) $\lambda$ とから、(4)式に従って、現時刻 $t$ でのゲインベクトル $k_n(t)$ を形成するものであり、また、遠端入力信号ベクトル $x_n(t)$ と、更新されたゲインベクトル $k_n(t)$ と、直前時刻 $t-1$ における状態遷移行列 $P_n(t-1)$ と、忘却係数 $\lambda$ とから、(5)式に従って、現時刻 $t$ における内部状態変数行列 $P_n(t)$ を形成するものである。形成された現時刻 $t$ でのゲインベクトル $k_n(t)$ 及び内部状態変数行列 $P_n(t)$ は、当該内部状態更新部102に内部保有されると共に、ゲインベクトル $k_n(t)$ は、適応フィルタ部103に与えられる。

【0031】なお、この内部状態更新部102にも、後述するように、ブロックサイズ制御部101から、タップ数制御信号 $BC (=n)$ が与えられており、タップ数制御信号 $BC (=n)$ に応じた次元のゲインベクトル $k_n(t)$ 及び内部状態変数行列 $P_n(t)$ を生成するようになされている。ここで、内部状態変数行列 $P_n(t)$ の次元を増大させる場合は、後述する(7)式による。また、ゲインベクトル $k_n(t)$ の次元は、内部状態変数行列 $P_n(t)$ の次元や、遠端入力信号ベクトル $x_n(t)$ の次元が増大されると、増大されるものである。

【0032】ブロックサイズ制御部101は、遠端入力信号 $R_{in}$ 及び又は近端入力信号 $S_{in}'$ の入力状態から、当該エコーキャンセラ1を初期化する必要があるか否かを判断し(言い換えると、各種のベクトルや行列 $h'_n(t)$ 、 $k_n(t)$ 、 $P_n(t)$ を初期化する時期を判断し)、初期化する必要がある場合には、タップ数を規定するタップ数制御信号 $BC (=n)$ を1に初期化させた後、時刻 $t$ が更新される毎にタップ数制御信号 $BC$ を1インクリメントし、タップ数制御信号 $BC$ が予め設定された最大タップ数 $p$ に達した後は、時刻が経過しても、タップ数制御信号 $BC$ の値を最大タップ数 $p$ に維持させるものである。以上のように、初期化直後においてのみ時刻の経過に伴って更新されるタップ数制御信号 $BC$ は、内部状態更新部102及び適応フィルタ部101へ出力される。

【0033】加算器Rは、エコーETが重畳されている近端入力信号 $S_{in}'$ から、適応フィルタ部103からの疑似エコー信号ERを減算してエコーを消去するものである。

【0034】以上のような各部からなるこの実施形態のエコーキャンセラ1は、全体を通しては、図2のフローチャートに示すように動作する。なお、図2における処理ループは、各時刻で1回処理されるものである。

【0035】新たな時刻 $t$ になるとまず、ブロックサイズ制御部101によって、例えば、遠端入力信号 $R_{in}$ と近端入力信号 $S_{in}'$ とが監視され、両者の関係から動作モードが判断される(ステップS1)。例えば、遠端入力信号及び近端入力信号、又は、両信号のどちらか一方が一定時間入力されない状況(音声レベルに達して

いない状況)にあるか否かにより、疑似エコー信号ERを生成する適応動作の初期化を行なうか否かを判断する。

【0036】初期化を行なう場合には、ブロックサイズ制御部101から値が1であるタップ数制御信号BC(=n)が内部状態更新部102及び適応フィルタ部1

$$P_n(t-1) = \alpha$$

これに対して、ステップS1の判断で初期化が不要であるという結果を得ると、ブロックサイズ制御部101は、今までのタップ数制御信号BC(=n)が既に最大タップ数pに達しているか否かを確認し、達していなければ、1インクリメントしたタップ数制御信号BC(=n)を内部状態更新部102及び適応フィルタ部103へ出力して次元の拡大処理を実行させ、一方、最大タップ数pに達していると、最大タップ数pのタップ数制御信号BC(=n)を内部状態更新部102及び適応フィルタ部103へ出力して次元の拡大処理を実行させないようにさせる(ステップS3)。

$$P_n(t-1) = \begin{pmatrix} \alpha & 0 \\ 0 & P_{n-1}(t-1) \end{pmatrix} \quad \text{---(7)}$$

$$h'_n(t-1) = \begin{pmatrix} 0 \\ h'_{n-1}(t-1) \end{pmatrix} \quad \text{---(8)}$$

その後、次元の拡大動作の実行の有無を問わず、内部状態更新部102によって、上述した(4)式及び(5)式に従って、現時刻tでのゲインベクトル $k_n(t)$ 及び内部状態変数行列 $P_n(t)$ が形成される(ステップS4)。続いて、適応フィルタ部103において、上述した(3)式に従って、現時刻tでのタップ係数ベクトル $h'_n(t)$ が形成される(ステップS5)。なお、これらの演算処理時に利用される遠端入力信号ベクトル $x_n(t)$ の次元も、当然に、そのときのタップ数制御信号BC(=n)の値による。

【0040】そして、適応フィルタ部103において、上述した(2)式に従って、現時刻tでの疑似エコー信号ERが形成され、加算器Rにおいて、疑似エコー信号ERの減算によるエコー消去動作が実行される(ステップS6)。

【0041】このようにして現時刻tでの一連の処理が終了すると、ステップS1に戻って、次の時刻(t=t+1)の処理に進むことになる。

【0042】以上のような図2に示す処理により、初期化が必要となったときには、有効タップ数が1での適応動作を実行し(S1、S2、S4~S6)、その後、最大タップ数pに達するまで有効タップ数を時刻毎に1ずつ増大させた適応動作を実行し(S1、S3(タップ数の更新を伴う)、S4~S6)、最大タップ数pに達した以降はそのタップ数pでの適応動作を実行する(S1、S3(タップ数を更新せず)、S4~S6)。

03へ出力され、このとき、内部状態更新部102は、(6)式に示すように、直前時刻t-1の内部状態変数行列 $P_n(t-1)$ を初期パラメータ $\alpha$ (固定値)だけを有する1×1の行列に設定する(ステップS2)。

【0037】

---(6)

【0038】ここで、1インクリメントされたタップ数制御信号BC(=n)が与えられた内部状態更新部102は、直前時刻t-1の内部状態変数行列 $P_n(t-1)$ を、(7)式に従って、次元が1だけ大きい行列に更新し、また、1インクリメントされたタップ数制御信号BC(=n)が与えられた適応フィルタ部103は、直前時刻t-1のタップ係数ベクトル $h'_n(t-1)$ を、(8)式に従って、次元が1だけ大きい行列に更新する。

【0039】

【数5】

【0043】上記実施形態によれば、内部状態更新部と適応フィルタ部の操作について、適応動作を再度やり直す初期化開始時点からタップ数を逐次増加させるようにしたので、エコーパスの伝達特性へ追従し直す適応動作の初期化時における演算量を削減することができる。

【0044】また、エコーパスのインパルス応答が比較的短い場合には、このように演算量を削減しても、タップ係数をより速くエコーパスの伝達特性に収束させることができる。

【0045】さらに、適応フィルタ部のタップ係数等の各種パラメータは、タップ数が増加された際にも、次の時刻へ継承されるため、収束動作がとぎれることなく、速やかな収束動作を実現することができる。

【0046】なお、上記実施形態においては、RLS法に適用したエコーキャンセラを示したが、タップ数に応じた次元を有するベクトルや行列等で表される時刻毎に逐次更新される内部状態量を利用して、タップ係数(ベクトル)を形成するアルゴリズムを採用しているエコーキャンセラであれば、本発明を適用することができる。例えば、カルマンフィルタ法や学習同定法等を利用したエコーキャンセラに本発明を適用することができる。

【0047】また、上記実施形態においては、ハイブリッド回路のインピーダンス不整合によるエコーを消去するエコーキャンセラを想定しているが、スピーカからマイクロホンへ回り込んだエコーを消去するエコーキャンセラに本発明を適用することができる。

【0048】

【発明の効果】以上のように、本発明によれば、内部状態更新部と適応フィルタ部の操作について、適応動作を再度やり直す初期化開始時点からタップ数を逐次増加させるようにしたので、エコーパスの伝達特性へ追従し直す適応動作の初期化時における演算量を削減でき、また、エコーパスのインパルス応答が比較的短い場合など、タップ係数をより速くエコーパスの伝達特性に収束させることができる。

【図面の簡単な説明】

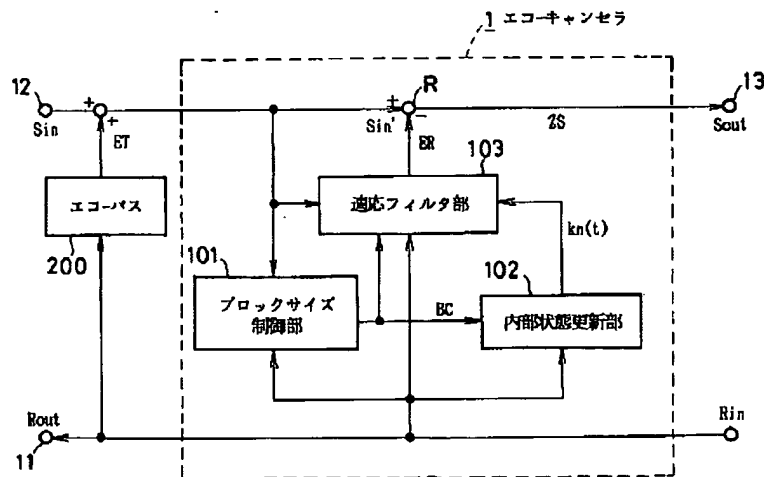
【図1】実施形態の構成を示す機能ブロック図である。

【図2】実施形態の動作を示したフローチャートである。

【符号の説明】

1…エコーキャンセラ、101…ブロックサイズ制御部、102…内部状態更新部、103…適応フィルタ部、R…加算器。

【図1】



【図2】

